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UNITED NATIONS AND COUNTRY REPORTS ON THE IMPLEMENTATION OF THE RESOLUTIONS OF THE THIRTEENTH UNITED NATIONS REGIONAL CARTOGRAPHIC CONFERENCE FOR ASIA AND THE PACIFIC

Status of cartographic activities in the United States of America

Paper submitted by the United States of America**

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** Prepared by the National Imagery and Mapping Agency, National Ocean Service, and the United States Geological Survey.

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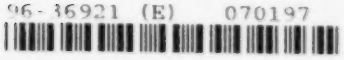

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INTRODUCTION

Since the Thirteenth United Nations Regional Cartographic Conference for Asia and the Pacific, U.S. cartographic activities have expanded to include advances in computer technology, remote sensing, geospatial geographic information systems, and inertial and satellite positioning systems.

All mapping and charting activities in the United States have been influenced by the development of automated cartographic techniques and equipment. Computers are applied to a broad spectrum of cartographic activities, including compilation, revision, maintenance, and production of topographic, orthophotographic, and image maps and aeronautical and nautical charts.

Advances in computer technology over the last decade have prompted Federal mapping and charting agencies to build digital data bases that are useful to the study of geology, soils, hydrology, land use, and land cover. A major achievement since 1987 has been the development of standards for digital cartographic data throughout the cartographic community.

The National Imagery and Mapping Agency (NIMA) of the U.S. Department of Defense (DOD) is responsible for the preparation of maps, charts and geodetic products on a worldwide (international) basis to meet national defense requirements and for the preparation of nautical and aeronautical products to support the safety of navigation. The U.S. Geological Survey (USGS) of the U.S. Department of the Interior (DOI) has the national responsibility for preparing and making available multi-purpose maps and base cartographic data in a variety of forms. In recent years, the USGS has concentrated on digitizing base categories of data on topographic maps, such as hypsography, hydrography, and transportation systems, to create a National Digital Cartographic Data Base (NDCDB). Other Federal agencies are responsible for collecting additional map data of public value. The National Ocean Service (NOS) monitors, assesses, and forecasts conditions in the coastal and oceanic environment to support effective management, promoting a healthy, safe, and economically productive coastal and oceanic environment for present and future generations. NOS is the primary civil agency within the U.S. Federal Government responsible for the health and safety of the nation's coastal and oceanic environment. As part of the National Oceanic and Atmospheric Administration (NOAA), the National Ocean Service provides a wide range of products and services, established on the best scientific basis, for the protection of life, property, and the environment.

Recent activities are discussed under the following headings:

- Geodesy and Geophysics
- Topographic Mapping
- Hydrography and Oceanography
- Aeronautical Charting
- Geographic Names
- Digital Cartography
- Remote Sensing/Imagery Processing
- Global Change
- Other Projects

Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Federal Coordination

On April 11, 1994, the President of the United States issued Executive Order 12906, "Coordinating Geographic Data Acquisition and Access: The National Spatial Data Infrastructure." The order assigns to the Federal Geographic Data Committee (FGDC) the responsibility of coordinating the Federal Government's development of the National Spatial Data Infrastructure (NSDI). The order establishes a National Geospatial Data Clearinghouse; requires that Federal agencies document their geospatial data using the FGDC's metadata standard and provide public access to the metadata through the clearinghouse. The order also requires the FGDC to develop standards, to coordinate the development of a National Digital Geospatial Data Framework; and to explore cooperative participatory efforts with State, local, and tribal governments, the private sector, and other non-Federal organizations. The FGDC approved a metadata standard for geospatial data in June 1994. Federal agencies are now beginning to use the standard and the FGDC has conducted numerous workshops and training sessions for all levels of government, as well as the private sector in implementation. Guidelines for the clearinghouse have also been issued with several hundred Federal and State agencies participating in the establishment of clearinghouse nodes. The FGDC continues to provide assistance in setting up these nodes and has initiated work to make available a variety of tools for clearinghouse users to aid in the search and retrieval of data. A concept of a framework of widely used common themes of data has been developed. The framework concept is now being tested in a series of pilot projects and will be further developed by continued research and demonstration projects. As part of NSDI implementation, public forums will continue to be held to develop and take action on strategies for cooperation among all sectors of the geospatial data community.

Other Mapping Organization Data

The USGS adds data produced by other mapping organizations to the National Digital Cartographic Data Base (NDCDB) and uses these data in the digital revision process. A USGS practice is to use other organizations' data to the fullest extent possible whenever it is practicable and economical.

To encourage cooperative efforts with other organizations to produce and share digital data, guidelines have been developed for acceptance of base category data into the NDCDB. At the present time, these guidelines address acceptance criteria only for base cartographic data collected from USGS source graphics.

GEODESY AND GEOPHYSICS

Within the NOS, the National Geodetic Survey (NGS) applies state-of-the-art methods of precise positioning and advanced geodetic, photogrammetric, and remote sensing techniques to establish and maintain a consistent national coordinate system and to support mapping, charting, navigation, boundary determination, property delineation, infrastructure development, resource evaluation surveys, and scientific applications. Activities are discussed below.

Geodetic Networks

The traditional role of NGS has been to establish, develop, and maintain the National Geodetic Reference System (NGRS). NGRS is currently comprised of approximately 1.5 million precisely located points that serve as the common base of reference for latitude, longitude, height, scale, orientation and gravity measurements throughout the United States. NGRS, therefore, supplies the framework for the multitude of surveying, mapping and construction projects conducted every day. In the last few decade these traditional uses for position control have been joined by a diversity of additional program dependent on highly accurate, time-dependent spatial reference information. As a result, NGS is developing a spatial reference system that will satisfy virtually any application throughout the Nation. The new system is named the National Spatial Reference System (NSRS). The internal consistency of NSRS will facilitate the application of GPS technology and enable the full use of its high accuracy.

National Spatial Reference System

New electronic navigation systems integrate electronic chart data with satellite positioning, as well as radar, sonar, and telemetered environmental information. In order to meet the Nation's navigation and other positioning needs, the existing coordinate reference system must be renovated to provide the higher accuracy and different accessibility needed for use with the Global Positioning System (GPS). The digital revolution in mapping, charting, and surveying requires a NSRS consisting of the following components: (1) a network of monumented points having four-dimensional positions, (2) a set of GPS Continuously Operating Reference Stations (CORS), (3) high accuracy orbits of the GPS satellites, and (4) a highly accurate geoid.

The NSRS provides a common geographic framework and the foundation of the Nation's spatial data infrastructure. The NSRS is the basis for mapping, charting, navigation, boundary determination, property delineation, infrastructure development, resource evaluation surveys, and scientific applications.

NGS is making progress toward the NSRS, responding to the demand for increased accuracy and accessibility to coordinates. In over 70% of the states, NGS has completed accuracy upgrades to the statewide networks of reference stations, with priority given to coastal areas. In partnership with the states, NGS provides a basic high accuracy framework with 100-kilometer station spacing and assists with completion of more dense station spacing through support and technology transfer. During FY 1996, NGS will support this objective by completing surveys, analysis, and data base loading for the horizontal and vertical components of NSRS in the States of West Virginia, North Carolina, South Carolina, Ohio, Nebraska, South Dakota, and Minnesota.

To provide greater accessibility to the NSRS, NOAA is cooperating with other Federal agencies to establish a network of CORS to support differential GPS applications in navigation and positioning. The CORS being established by NGS, U.S. Coast Guard, Corps of Engineers, and Federal Aviation Administration to support marine, river, and air navigation are being configured so that they also meet positioning needs of surveying, mapping, and GIS users. During FY 1996, NGS will add 45 CORS with data available on-line. This will bring the total to 75, out of a projected total of 100 for the CORS data network. CORS are fixed GPS tracking stations that operate 24 hours a day, 7 days a week, collecting observations that enable users to cost effectively utilize GPS techniques. CORS enable users to achieve the highest accuracy positioning of fixed and moving GPS receivers, minimize costs by reducing or eliminating the need for project-related base stations, and ensure that new positional observations are accurately referred directly to the NSRS. NGS will provide positional integrity monitoring for the CORS network and efficient CORS data availability for users.

Operation of the CORS data network will include development of an improved national geoid model, GEOID96, to facilitate the use of GPS for leveling. NGS has produced a merged file of NGS and National Imagery and Mapping Agency (NIMA) gravity data, generated supporting gravity anomaly data files from satellite altimetry-derived gravity by Sandwell and Smith, and continued evaluation of test geoid models by means of GPS heights on vertical benchmarks. The GEOID96 computation will be completed by November 1996.

Geoid Height and Deflections of the Vertical

GEOID96 geoid heights are based on the Geodetic Reference System of 1980 (GRS80), and they are appropriate for converting Global Positioning System (GPS) ellipsoidal heights based on the NAD 83 datum into orthometric heights based on the NAVD 88 datum.

GEOID96 was developed using gravity data from NGS and the National Imagery and Mapping Agency (NIMA); from terrain data from NOAA's National Geophysical Data Center (NGDC); from the joint NASA/NIMA global geopotential model; and from numerous cooperative survey projects.

GEOID96 consists of a grid of model geoid height values with a 2-minute by 2-minute spacing in latitude and longitude. Software program GEOID is provided with GEOID96 to simplify extracting and interpolating values from the grid to discrete points. GEOID96 displays about 2.5 cm accuracy (one sigma) between points spaced at 50 km or greater. The long wavelength discrepancies apparent in earlier geoid models have been removed by the use of GPS on leveled bench marks in the conterminous United States. This trend removal does cause GEOID96 to be biased relative to a geocentric ellipsoid; this bias is deliberate. GEOID96 was developed to support direct conversion between NAD 83 GPS heights and NAVD 88 orthometric heights.

NGS is also publishing an improved gravimetric geoid height model for the conterminous United States called G96SSS that is suitable for scientific investigations. Its geoid heights are referred to GRS80 and the computations have been performed in the ITRF94 reference frame. G96SSS produces accuracies of 1 cm plus 1 part per million of the distance between selected points. G96SSS was designed as an unbiased, geocentric geoid. The G96SSS geoid model is not suitable for direct conversion between NAD 83 GPS heights and NAVD 88 orthometric heights.

Along with these geoid models, NGS is publishing an improved surface deflection of the vertical model called DEFLEC96. These deflections are based on GRS80 and are appropriate for Laplace corrections and deflection corrections based on NAD 83 values. DEFLEC96 is developed from the same gravity and terrain data and GPS observations at leveled benchmark data sets that were used to compute GEOID96, insuring compatibility. DEFLEC96 consists of a grid of model deflection values with a 2-minute by 2-minute spacing in latitude and longitude. Software program DEFLEC is provided with DEFLEC96 to simplify extracting and interpolating values from the grid to discrete points. DEFLEC96 was developed from gravity data held by NGS and NIMA, from terrain data available from NGDC, the joint NASA/NIMA global geopotential model, and from numerous cooperative survey projects. DEFLEC96 displays about 1 arc-second accuracy (one sigma) in comparison with astronomic and geodetic (NAD 83) latitudes and longitudes. Accuracy is correlated with elevation and terrain roughness, with significantly better accuracy evident in the eastern United States.

All of the geoid height and deflection of the vertical components mentioned here are planned for release in mid-October 1996. They will be available on a single CD-ROM from NGS' Information Services Branch.

Technology Transfer

A wide variety of national programs depend on NGS for accurate, timely geospatial reference information, i.e., geodetic data. Among these, the U.S. Geological Survey uses geodetic data to understand and anticipate earthquakes, volcanic eruptions, and other disastrous geophysical events. The Federal Emergency Management Agency depends on geodetic data to delineate flood plains for insurance and natural disaster mitigation programs throughout the United States. The Federal Communications Commission uses geodetic data to identify the locations of transmitters and other broadcast facilities in its nationwide facilities licensing program. The Federal Aviation Administration needs geodetic data to manage air navigation throughout the country. Other NOAA Divisions use geodetic data to administer hydrographic survey, coastal zone management, and wetlands delineation programs.

Recently NGS has been focusing attention on the concept of a Land Information System (LIS). LIS interrelates identity, use, and other attributes of land parcels, maps, and paper records. These attributes are integrated with a geodetic reference framework to form a unifying foundation by linking its component layers of cartographic data. At the local level, a diverse multitude of organizations use such information structures based on a geodetic framework. It would be virtually impossible to list all of the organizations and activities that use geo-coded inventories of their resources and their customers (or demands for their resources). For exampl., electrical utilities encode transformer locations, matching those with customers' addresses in a way that can be stored, recalled, and updated. Similarly, school boards track the size and composition of their constituencies, municipal governments map the locations of needed road repairs, etc. Each organization gains efficiency from this organized, graphic presentation of inventories and resource flows.

These geographic reference bases serve their purposes extremely well, but if they exist independently without the ability to combine or integrate information, their value is restricted to the original purpose for which the information was produced. The real value and purpose of an accurate, up-to-date spatial reference system is its ability to satisfy various potential users of geospatial information products in a way that is universally

compatible. That is what NSRS will provide when it is used as the foundation of an LIS in support of NSDI.

A great many areas of the country urgently need comprehensive, timely land information derived from the National geodetic survey data base for tax assessment, land-use planning, construction and maintenance of public utilities, and many other services. The widespread use of computers and improved techniques for acquiring land data combine to make LIS an ideal way to meet these national needs. NGS is currently coordinating the development of the FGCS & quot; Multipurpose Land Information Systems Guidebook & quot; for establishing land information systems using the LIS concept. Generic LIS specifications and the digital geospatial metadata standards for geodetic data are being developed by NGS to support our Nation's surveying and mapping requirements and NSDI.

Astronomic Azimuth and Positioning

Continuing requirements for astronomic azimuth and positioning led NIMA to develop a new astrolabe, the A35M. This state-of-the-art instrument will replace the CCD-equipped Wild T-4 theodolite and VUGTK astrolabe for all future work requiring astronomical observations.

Global Positioning System (GPS) Satellite Orbit, Surveys and Applications

The NIMA operates a worldwide GPS satellite tracking network with stations located in Argentina, Ecuador, Australia, Bahrain, United States Naval Observatory, China, and England. Data from the NIMA network and the five U.S. Air Force GPS monitor stations are used by NIMA to compute precise orbits and satellite clock offset estimates for all the GPS satellites. NIMA's precise ephemerides and tracking data provide quality assurance for the Air Force's GPS operations and support NIMA's geodetic positioning work.

The precise ephemerides and satellite clock values are produced using a three day sliding fit. The middle day is then released for distribution using the National Geodetic Survey (NGS) Special Product #3 (SP3) international format. The daily ephemeris are zipped self extracting files and are available on the World Wide WEB at 164.214.2.53. The NIMA stations are automated and are remotely controlled from the NIMA GPS Network Control Center in St. Louis, Missouri. Most of NIMA's GPS stations use Ashtech ZY-12 receivers and are full Precise Positioning Service (PPS) capable of direct Y-code tracking, the exception is China where Ashtech Standard Z-12s are used.

NIMA has nearly 100 Ashtech GPS receivers in its inventory for geodetic positioning work. Absolute (point) positions can be computed from a single receiver's data to 0.25-0.5 m accuracy in each component in the World Geodetic System (WGS) 1984 using software developed at NIMA. The GIPSY-OASIS software developed by the Jet Propulsion Laboratory (JPL) has been obtained by NIMA which will further increase high accuracy positioning capabilities.

During the last three years, 15 international cooperative GPS survey projects have been carried out using absolute and relative positioning techniques in Africa, Asia, Europe, and Central and South America. Additionally, NIMA has performed four GPS network adjustments for countries who supplied the GPS observations.

Phase one of the Sistema de Referencia Geocentrico para America del Sur (SIRGAS) project conducted in cooperation with the International Association of Geodesy, The Pan American Institute for Geography and History, the

Deutsches Geodaetisches Forschungs Institut, and the South American countries is nearing completion. Phase one of the project is the establishment of a high accuracy control network for the continent. Additional phases will be conducted to densify the control in each country.

Gravity Surveys and Data

NIMA continues to collect and evaluate gravity data from around the world. NIMA conducted a large gravity survey in Alaska and supported surface and airborne gravity surveys in Greenland (US Naval Research Laboratory, Denmark's Kort-og Matrikelstyrelsen) and Brazil (University of Leeds).

NIMA has acquired a second absolute gravity meter from Micro-g. NIMA survey personnel conducted 13 absolute gravity measurements around the world. Measurements were made at sites in the Czech Republic and Slovakia, Morocco, Hungary, United Kingdom, Diego Garcia, Greenland and South America.

Existing gravity data are also being obtained for large areas in Southeast Asia, the former Soviet Republics and Eastern Europe.

The GRAVREP software was acquired for estimating gravity data from geological, terrain and altimetry data in areas where point gravity data are not available.

A new data management system has been developed and recently installed to store and retrieve all of NIMA's point gravity anomaly data, gravity products and documentation.

World Geodetic System 1984 (WGS 84)

The NIMA produces mapping, charting, geodetic, gravimetric, and digital products in support of the U.S. Department of Defense (DoD). These products are referred to a single geocentric coordinate system because of accuracy and user interface considerations. Such a system also is needed to support the widest possible range of applications (local, worldwide), to relate information from one product to data obtained from another source, and to ensure a smooth transition in product use from one part of the world to another. Such a geocentric system, called the world geodetic system, provides the basic reference frame and geometric figure for the earth, models the earth gravimetrically, and provides the means for relating positions on various local geodetic systems to an earth-centered, earth-fixed coordinate system. This world geodetic system serves as the framework for NIMA products and worldwide DoD operations.

The second edition of NIMA Technical Report 8350.2, Department of Defense World Geodetic System 1984, was published in September 1991 (NIMA Stock No. NIMATR83502WGS84) and a number of datum transformations were added in an insert to the report in August 1993. The second edition includes new transformation constants for geodetic datums and reference systems, deletion of multiple regression equations for small and isolated areas, and changes in symbols for the ellipsoidal and mean sea level heights. The WGS 84 Earth Gravity Model, complete through degree and order 180, has been declassified.

NIMA is distributing a Mapping Datum Transformation software package for datum transformation and coordinate conversions (NIMA Stock No. MADTRANIBMPC, Edition No. 4.2). The program allows input from geodetic, Universal Transverse Mercator (UTM), or the Military Grid Reference System (MGRS) coordinates. Over 100 datums are available for transformation to or from WGS

84. Output is automatically presented as geodetic, UTM and MGRS coordinates. NIMA will continue to develop and improve transformations between local datums and WGS 84.

NIMA is currently working on improvements to WGS 84 that will allow the realization of a worldwide ±1 meter three dimensional reference system. To do this, NIMA is working with the National Aeronautics and Space Administration to develop an improved Earth Gravity Model (EGM) using all of the new data that have become available since the original development of WGS 84 in the early 1980s. The new EGM will be used to generate an improved geoid with an accuracy goal of ±0.5 to 1.0 meter over the entire earth. The enhanced WGS 84 geoid will be used to determine all mean sea level heights for NIMA products and as a means of unifying the myriad vertical datums used around the world. NIMA is also working on a project with the International Association of Geodesy, the Pan American Institute for Geography and History and the countries of South America to redefine the South American Datum. The project's goal is to establish a high precision continental network of geodetic control stations and then extend this control within each of the countries.

World Geodetic System 1984: A Three-Dimensional Reference Frame for Global Mapping, Charting and Geodetic Applications

The National Imagery and Mapping Agency's (NIMA) latest version of the World Geodetic System (WGS 84) provides an accurate reference frame, earth gravitational model, normal gravity formula, geoid and transformation constants with 115 local and regional datums covering all seven continents and many islands over major ocean areas. WGS 84 represents NIMA's state-of-the-art modeling of the earth from a geometric, geodetic, and gravitational standpoint using contemporary data techniques and technology. NIMA's efforts have resulted in significant simplification of the Mapping, Charting and Geodetic (MC&G) complexity and have improved the quality and accuracy of NIMA products worldwide.

Global Geospatial Information and Services Initiative

The National Imagery and Mapping Agency's Global Geospatial Information System (GGIS) initiative represents NIMA's response to recent changes in the global political and technological climate of the world. It represents a visionary interoperability approach to address the new challenges for the Mapping, Charting and Geodesy (MC&G) community and the commitment to worldwide information management. GGIS will be compatible with the most sophisticated geographic information system technologies. It employs user-accessible databases in a "data warehousing" or federated architecture. GGIS will contain a wide variety of information and datasets will be compliant with international, government and industry standards. Layers of the database will include orthorectified and geocoded imagery, precise geodetic positions, centerline features with the necessary attributes, terrain and seafloor elevations, gravity and safety to navigation data. Information describing the data will accompany the datasets to support the exploitation software packages used by the customer. GGIS will employ fiber optics, asynchronous transmission and communication satellites to establish high speed reliable highways of information between the producer and customer. Customers will have powerful compact computers which have the capability of receiving heavily attributed datasets and allow tailored applications in offices, on ships, in space, or wherever high quality geospatial information is required.

TOPOGRAPHIC MAPPING

Primary (Large)-Scale Mapping

National coverage was completed for the 7.5-minute topographic quadrangle series in 1991. These maps are now being digitized and the data files used to support GIS applications as well as the map revision program. Modern product generation capabilities have been developed to output graphic products from the digital files. The NMD map revision process for primary-scale maps is predominantly digital and is characterized by feature extraction from Digital Ortho Quadrangles (DOQ's), with simultaneous collection and revision of representative DLG's.

Intermediate-Scale Mapping

Topographic editions are available for all 1,826 1:100,000-scale quadrangle maps of the conterminous United States. Additionally, 1:50,000-scale metric topographic quadrangle maps are being produced on a fully reimbursable basis in support of NIMA's domestic mapping requirements. Several of these NIMA maps were completed in fiscal year 1996, with additional projects planned for fiscal year 1997 and beyond.

Small-Scale Mapping

Topographic map coverage of the United States is complete at 1:250,000 scale, totaling 635 sheets. The series is currently maintained by the USGS. The USGS implemented a new revision policy to replace the existing series with an updated series in side panel and metric format, prepared from paneled reductions of 1:100,000-scale topographic quadrangles. Digital terrain data for the 1:250,000-scale map series are available.

Other small-scale maps at 1:500,000 and 1:1,000,000 scale include the State base map series.

Special-Purpose and Thematic Mapping

Special-purpose maps are prepared from existing map bases and information collected from various sources to meet the needs of Federal, State, and regional agencies. Maps of national parks, monuments, and historic sites, produced by the USGS at various scales for the National Park Service, are examples of special maps. Additionally, various thematic maps emphasizing a single topic or theme, such as geology or hydrology, are also prepared and published by the USGS for the U.S. Government and scientific community.

The USGS continues to support the U.S. Antarctic Program by conducting geodetic ground surveys and by compiling topographic maps of the continent. To date, 95 maps of Antarctica at 1:250,000 scale have been published, as well as topographic maps at 1:50,000 scale, 1:1,000,000 scale and smaller, and Landsat image maps at several scales.

Land Use and Land Cover Mapping

The USGS continues its involvement in preparing land use and land cover products for the United States. The program provides the only systematic inventory of land use and land cover data that is nationwide and features a uniform classification system at standardized scales. The maps and digital data are used by the Federal, State, and private sectors to support resource

management, planning, development, environmental monitoring, and GIS activities.

Completion of land use and land cover and associated maps, primarily at 1:250,000 scale, for the conterminous United States and Hawaii was accomplished in 1987. The associated maps include political units, hydrologic units, and census county subdivisions; Federal and State ownership overlays were prepared under State cooperative programs. Digitizing of the graphic products was completed in 1992. The data are distributed by the USGS in both vector and composite-theme grid cell format. Statistical summaries by quadrangle are also available.

HYDROGRAPHY AND OCEANOGRAPHY

The NOS' Coast Survey is the Nation's chart maker. It is responsible for nautical chart data collection and information programs for U.S. waters. The Survey's Marine Chart Division collects marine navigational data to construct and maintain nautical charts, Coast Pilots, and related marine products for the United States. The Hydrographic Surveys Division directs programs for ship and shore-based hydrographic survey units and conducts general hydrographic survey operations. Hydrographic and other marine databases used by Coast Survey are maintained by the Marine Geology and Geophysics Division of the National Geophysical Data Center. The Survey's Ocean Products and Services Division maintains a national network of water-level observing stations, and is pioneering the development of real-time monitoring of water levels in harbors and ports. In addition to providing vital tide and current information to the Nation's mariners, this work provides the foundation data for tidal prediction throughout the Nation and is used by the National Weather Service in its storm surge warning program.

During July and August 1996, the Coast Survey participated in the effort to locate and identify wreckage of TWA Flight 800 located on the sea floor off Long Island, New York.

Bathymetric Mapping

The NOS Bathymetric Mapping Program was terminated in August 1992 to focus resources on the development of shallow water multibeam capabilities for nautical charting.

Hydrographic Surveys

Hydrographic surveys were conducted over the last year using three NOAA ships and two Coast Survey mobile field parties. Surveying occurred along the west coast of the United States and in the waters of southern Alaska and California. Surveys were also conducted along the east coast of the United States and the Gulf of Mexico. The majority of these surveys were basic hydrographic surveys. However, special field examinations and side scan sonar surveys also took place.

Side Scan SONAR Mapping

The results of a field evaluation of a prototype High Speed High Resolution Side Scan Sonar (HSHRSSS) clearly demonstrated the utility of a HSHRSSS to detect features of hydrographic significance, i.e., wrecks and obstructions, at high speed in shallow water. Based on the demonstrated utility, NOAA developed a technical specification, conducted a competitive procurement, and awarded a contract to Klein Associates of Salem, New Hampshire, U.S.A. The contract was for the purchase of one HSHRSSS with the option to purchase 10 additional HSHRSSS's.

The Coast Survey has acquired the DELPH-SONAR digital recording and processing Side Scan Sonar (SSS) systems for deployment on its hydrographic field units. The DELPH system operates on a 120 Mhz Pentium Personal Computer and will digitize the analog outputs of NOAA's existing EG&G 260 recorders. In addition to being connected to the SSS recorder, it will receive positioning, time, and event mark information from the hydrographic data acquisition system. The digital, geo-referenced, sonar images are displayed on a high resolution computer monitor and written to the DELPH's internal hard disk in a compressed format. Processing of this data on the DELPH involves

identification of sonar contacts, image enhancement to better define the contact, and measurement of contacts to determine location and height off the bottom. The significant features are then imported into the hydrographic data processing system.

Vertical-Beam Hydrographic Data Collection and Processing Systems

In support of the collection of vertical-beam echo sounder and SSS data, the Coast Survey continued to support the Hydrographic Data Acquisition and Processing System (HDAPS) for ship and ship-based hydrographic survey launches. Coast Survey continued its implementation of the commercial survey application HYPACK on small boat and shore-based hydrographic survey launches. At present, more survey platforms use HYPACK for data collection than HDAPS. Both HYPACK and HDAPS are configured to provide positioning, time, and event mark information to the DELPH-SONAR system. The processing of the hydrographic data continues to be done HDAPS. Data collected in HYPACK is converted to the HDAPS format for processing. All hydrographic survey platforms are equipped with Differential Global Positioning System (DGPS). DGPS correctors are provided from both the U.S. Coast Guard radio beacon system or NOAA's own stand-alone "Fly-Away" systems. The NOAA "Fly-Away" DGPS operates with either an HF or VHF radio link.

Airborne Laser Hydrography

The Coast Survey maintains an active airborne lidar hydrography liaison program with the U.S. Army Corps of Engineers (USACE). The Coast Survey became involved with the USACE SHOALS (Scanning Hydrographic Operational Airborne Lidar Survey) system in 1988. SHOALS is a pod mounted, 200 Hz, 5 ns pulse width Nd:YAG laser bathymetry system that is currently flown aboard a Bell 212 helicopter operated by the NOAA Aircraft Operations Center.

The SHOALS system was built for the USACE by Optech, Inc., of Toronto, Canada, under a joint program with the Canadian Government. It is a private-contractor operated system, with maintenance and operation provided by John E. Chance & Associates, Inc. The Coast Survey assisted with the hardware, software, and test design of the system and is conducting surveys to evaluate the system's hydrographic capability. The results of these surveys will become an integral part of determining the best mix of survey platforms and techniques (lidar, side scan sonar, multibeam sonar, diver investigation) with which to accomplish the NOS charting mission.

Shallow Water Multibeam Hydrography Data Collection

In March, 1994 the NOAA Ship RUDE was outfitted with a Reson SEABAT 9001, Multibeam Bathymetric Sonar System to supplement the ship's hydrographic data collection capabilities. Critical targets, located by Side Scan Sonar (SSS), were developed using the SEABAT with full bathymetric bottom coverage over very small areas surrounding these targets. This reduced the ship's dependence on diver investigations to resolve these items. The SEABAT's multibeam data was acquired and examined with software developed within the Coast Survey. This processing scheme generated a small number of minimum depth values from the development area. These minimum depth values were manually entered back into the hydrographic data processing system.

In March of 1996 an upgrade to the RUDE multibeam system was installed. This upgrade involved the use of commercial off-the-shelf components for the data acquisition systems, a modern vessel motion sensor, and a new gyro. RUDE retained the vertical-beam hydrographic and SSS capabilities that have been

used in the past several years. Triton Technology's ISIS was installed to log all multibeam data and related sensors. Coastal Oceanographic's HYPACK software was implemented to provide line control and handle the traditional vertical-beam fathometer and SSS requirements. Both of these applications run on Pentium class computers with multiple serial ports. These new components also allow for additional survey sensors to be implemented in the future.

The Coast Survey procurement of the Compact Shallow Water Multibeam Sonar System, for installation on NOAA's 29 foot hydrographic survey launches, continues on track. These launches are carried by NOAA Ships RAINIER and WHITING and also operated by Coast Survey's shore-based survey parties. Delivery of the initial system(s) is anticipated in October 1996. A significant government test and evaluation program is planned in Seattle, Washington immediately following delivery.

Multibeam Hydrography Data Processing

The Coast Survey continues to make progress in developing a comprehensive "toolkit" for multibeam acquisition quality assurance (QA) and processing of shallow water multibeam (SWMB) data. Collaborative efforts are underway with the University of Rhode Island and the University of New Brunswick (UNB) in Canada. The goal is to develop a near real-time toolkit for on-line QA testing of SWMB sensor inputs, with emphasis on system performance, sonar coverage, and data accuracy.

The Coast Survey's Hydrographic Technologies Program and System Support Branch are working to integrate in-house processing tools into commercial multibeam processing applications. The goal is to meet NOS and international requirements for nautical charting, and to facilitate the rapid processing of the enormous quantities of data that the newer high-frequency SWMB sensors record.

The Coast Survey continues to play an active role with the US/Canada Hydrographic Commission Coastal Multibeam Working Group. In particular, the Coastal Multibeam Hydrographic Surveys Course developed by this working group will be offered again this June in St. Andrews, New Brunswick. The course has been well received at numerous international locations during the past year and is well attended by representatives from hydrographic organizations and hydrographic contractors from around the world.

On-the-fly GPS for Vertical Control of Hydrographic Surveys

The Coast Survey conducted a field experiment in 1995 associated with the use of on-the-fly GPS for vertical control of hydrographic surveys. The experiment was conducted in Galveston Bay, Texas involving cooperation between the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Army Corps of Engineers. The experiment included fifteen repeat hydrographic surveys of a triangular path with a tide gauge stationed at each apex and a tide gauge at the mid-point of one leg. GPS heights of the bottom were determined by combining the measured depths with the GPS height of an antenna mounted on the survey launch and the vertical separation between the GPS antenna and the acoustic transducer.

An error analysis on the multiple repeated depth measurements indicated a precision for the on-the-fly GPS vertical control of approximately 3 cm. A comparative analysis was conducted between the height of the free water surface as measured by the tide gauges and estimated from the on-the-fly GPS measurements. The analysis indicated an accuracy of approximately 5 cm for

the GPS on-the-fly measurements. A systems analysis is underway to examine the productivity implications of several potential operational techniques whereby GPS vertical control could be incorporated into Coast Survey's hydrographic surveys.

Data Quality Assurance for Multibeam Bathymetric Sonar

Data Quality Assurance (DQA) techniques are important tools by which a hydrographer in the field can determine if the survey data are valid representations of the physical environment. Such techniques can significantly reduce the likelihood that field work must be repeated to meet the survey requirements. The advent of wide applications of multibeam bathymetric sonars to hydrographic surveying in shallow water has given rise to the need for DQA techniques to detect random errors associated with slant range measurements and bias errors associated with incorrect refraction adjustments in the conversion from slant ranges to depths. The Coast Survey is working to extend techniques employed in its field testing of multibeam sonars to provide estimates of refraction induced depth errors for each beam. The Coast Survey technique estimates the off-nadir sector of the included survey angle which fails to meet the IHO depth standards.

Photogrammetry - Coastal Mapping

NOS's coastal mapping mission is carried out by the National Geodetic Survey (NGS). One of its principal responsibilities is to survey the coastline and provide accurate positions of the shoreline and other features that are used to construct NOS's nautical charts. Early coastal maps were based on topographic surveys performed with a plane table and alidade. Today, aerial photographs and photogrammetric methods are being used almost exclusively to survey the shoreline and provide topographic and planimetric data for nautical charting. To this end, NGS has developed techniques for precisely delineating coastal features using aerial photographs and analytical stereo photogrammetry. Techniques are currently being developed to utilize multispectral imagery for this purpose.

Determining the precise location of the shoreline is extremely important because the shoreline is the boundary that defines private, state, and Federal ownership. In areas where adequate water level datums have been established, photogrammetric methods are often the best approach for delineating the mean-lower-low-water (MLLW) and mean-high-water lines that are used to define offshore limits such as the United States territorial sea and the Exclusive Economic Zone, the marine segment of state boundaries, and riparian property lines.

NGS' area of photogrammetric responsibility includes all the coastal regions of the United States and its possessions, and the Great Lakes and their connecting navigable waterways. Overall coverage consists of approximately 95,000 miles of shoreline. Mapping information and photography are reacquired on varying cycles depending on the amount of change caused by cultural or natural forces.

NGS's final photogrammetric product consists of digital files tied to at least second-order geodetic control from which electronic or paper charts and maps are derived. The data is seamless across the files, making it possible to construct a variety of high-accuracy map products. The digital files are created using sophisticated technologies that capture information contained in photographic images. These files may also be used to create very precise geographic information system (GIS) base maps as well as GIS layers depicting

natural resources and cultural features. Multispectral imaging will be very useful in this regard. Other products generated from these activities include the aerial photographs themselves, digital multispectral imagery, and hard-copy maps.

Nautical Chart Production (U.S. Waters)

During Fiscal Year (FY) 1995 (October 1, 1994 through September 30, 1995), the Coast Survey published 202 new edition charts. The production of new charts has been suspended in order to concentrate resources on compiling new edition charts. The further expansion of computer-assisted chart compilation, described below, has contributed to a steady increase in the rate of production of new edition charts. As the end of FY 1996 approaches, the projected total of new edition charts to be published for the year is 235. Plans are to publish 300 new edition charts during FY 1997 and 350 new editions during FY 1998.

To further increase its production capacity, the Coast Survey is investigating the potential for contracting the end-to-end nautical chart production process. It is conceivable that contract personnel could be integrated with experienced in-house personnel to perform all functionality needed in the compilation process. A statement of work is being drafted to determine commercial availability of cartographic personnel.

Nautical Chart Maintenance Plan

The Office of Coast Survey has developed a new nautical chart maintenance plan to provide priority support to major U.S. ports. The maintenance plan originated from the continued erosion of fiscal and personnel resources in FY 95. To maintain the suite of nautical charts in a state of currency requires the annual publication of approximately 400 new editions, yet resource levels for FY 96 will sustain only 250 new editions. Therefore, a priority scheme was developed to support the majority of marine transportation's requirements with the resources available.

The set of charts that support the largest commercial ports, neighboring ports, and associated trade routes was chosen by analyzing data that rank U.S. ports both by the weight and value of goods moving through them. The location of the ports and their rank order of importance according to the new plan are shown in the accompanying figures.

While the plan does not support all ports on either tonnage or value listings, it does:

- Include 62% of the ports ranked by tonnage of goods and accounts for 91% of the total tonnage handled in all U.S. ports and harbors
- Include approximately 50% of the ports ranked by value of good and accounts for 98% of the total value of goods handled in all U.S. ports and harbors.
- Supports major ports of call within the continental U.S. that are visited by the cruise line industry.
- Support the Coast Survey priority scheme for hydrographic surveying and coincide with the most current and planned hydrographic survey activity.

- Include those areas where the most frequent and critical changes occur.

Nautical Chart Updating Service

The Coast Survey produces new editions of its nautical charts on schedules which vary from every 6 months to 12 years. During the period between new editions, the charts become obsolete. New information is constantly being received, for example, from NOAA hydrographic survey teams, from the U.S. Coast Guard (USCG) as they alter aids-to-navigation and from the U.S. Army Corps of Engineers as they dredge the federally maintained navigation channels.

Between new editions, critical changes to the charts are distributed using the USCG Local Notice to Mariners (NTM) and the National Imagery and Mapping Agency (NIMA) Weekly Notice to Mariners. These documents include a text description of critical chart changes which must be received, interpreted and manually applied by each chart owner. Users of NOS digital raster nautical charts must also use the Notice to Mariners publications and then look to their navigation software provider for the facility to manually apply those corrections to the digital file.

This method of chart correction is inadequate. The changes are hard to interpret, are time consuming to apply and the result is prone to error. The method of distribution is equally ineffective with the number of copies of the Notices to Mariners distributed being far smaller than the number of charts in use. In addition, chart corrections for a single edition can be spread over several NTMs which may or may not be readily available. The Coast Survey is experimenting with ways to provide a weekly update service for paper and raster nautical charts to improve this situation. The goal of this service is to provide easy to apply chart updates that are readily available and are always current with the latest NIMA and USCG Notices to Mariners.

The update method would have the Coast Survey compile all Notice to Mariner changes into digital raster chart files used in their current production environment. This compilation would be done weekly. For paper chart corrections, the small updated sections of the digital chart file would be cropped out, arranged on an 8 1/2" x 11" format, and transmitted on demand to chart sales agents or chart users. Laser and ink jet printers have successfully been used to plot a paper copy of these patches. Chart owners would then cut and paste the patches onto their charts at locations indicated on the correction.

For raster chart corrections, the old raster chart would be subtracted electronically from the new raster chart giving a file of the differences. These difference files would be distributed electronically. For the user, software would first display the raster chart then immediately overwrite it with the file of differences (i.e., the updates). If a "transparent color" is used where the file of differences has no data, that is, where the chart is unchanged, the result will be a corrected raster nautical chart.

In February, 1996, the Coast Survey completed a data base of all published USCG Notice to Mariner corrections to its charts. The methods and tools for using this data base to edit the raster chart files are being used daily in the production of new chart editions. These same methods and tools will be used for the update service. A special effort to fully apply the backlog of changes in the data base to the raster nautical chart files began in April, 1996. The transmission and plotting of paper chart patches has been

successfully demonstrated as has the "overwriting" method of correcting the raster nautical charts.

Production statistics are being estimated to insure that the Coast Survey has sufficient resources to produce this product. Many production and business issues remain to be addressed. Such issues include integrating the raster file update process with new chart production, quality control on a product being distributed weekly, and how much to charge.

Hydrographic Source Assessment System (HYSAS)/Master Seafloor Digital Database (MSDDB)

One of the major programs under the DHI is the Hydrographic Source Assessment System (HYSAS). HYSAS is a multi-agency, distributed system for the management of hydrographic and bathymetric data, as well as a gateway to existing MG&G source data libraries. Bathymetric and hydrographic data will be cataloged, evaluated with a standard set of algorithms, assessed for candidate hazards to navigation, and fused into a Master Seafloor Digital Data Base (MSDDB). The layers of the MSDDB will consist of a Navigation Sounding Layer (NSL), a Navigation Feature Layer (NFL), a gridded Bottom Model, a Geology Layer and an Acoustic Imagery Layer. The MSDDB will provide authoritative bathymetric data for the ocean floor, supporting production needs of NIMA and the U.S. Naval Oceanographic Office as well as serving as the data base to support new Navy digital products and data requirements. The source data and MSDDB Layers will be available on-line to all three DHI agencies to support new products and services through an electronic gateway.

Some of the capabilities provided by HYSAS/MSDDB are:

- Access to a comprehensive DHI agency-wide catalog of data
- Facilitate the retrieval of required data
- Search and extract best source data to satisfy requirements
- Evaluate and assess source data in support of accurate product generation
- Plan future source data collection and coordinate data acquisition activities and requirements
- Browse the inventory of source holdings for coverage and accuracy to support program/product generation
- Graphically display areas of useful source coverage and shortfalls in required data
- Document the characteristics of available source data

Navigation Safety System (NSS)

The development of the (NIMA) Navigation Safety System (NSS) began in 1994 with the objective to replace and enhance the functions and capabilities of the Automated Notice to Mariners System (ANMS) which is currently operating within the Marine Navigation Department at NIMA. The ANMS is a major hydrographic production system which produces the US Notice to Mariners and all NIMA Navigation Publications while also providing support to NIMA production systems in the compilation and maintenance of hard copy and digital charts. ANMS also maintains vital marine safety information data files and allows for remote query access into selected databases by standard and encrypted communications devices. NIMA's responsibility to provide marine safety information, products, and services are stated in Titles 10 and 44 of US Code, DoD Directive 5105.40, and the International Convention for the Safety of Life at Sea (SOLAS).

The NSS will maintain and store the Navigation Feature Layer (NFL) of the distributed Master Seafloor Digital Database (MSDDB) on the Hydrographic Source Assessment System (HYSAS). The NFL will contain spatial data, positional accuracy, and attribute information on all navigation features throughout the world. Uses of the NFL include support for Digital Nautical Chart (DNC) compilation, generation of DNC Updates, and hard copy chart compilation.

Digital Navigation Publications will be compiled and maintained on the NSS using NIMA's Text Product Standard (TPS). TPS text generation is based upon ISO 8879, Standard Generalized Markup Language (SGML). SGML will provide future text links between various NIMA digital products including features contained within the Sailing Directions and the DNC. Distribution of these publications will be on CD-ROM and hard copy.

The NSS will provide worldwide remote query access to NSS databases via the Global Geospatial Information and Services (GGI&S) network links, the Internet, and the public communication network (dial-up modems). Remote query users will be able to query the NFL, all information contained within the US Notice to Mariners, and various other vital marine safety information data. Interfaces to NSS Joint Agency Users for the maintenance of their databases resident within NSS will also be provided.

NSS completed its Preliminary Design Review (PDR) Milestone 11-12 September 1996 and is scheduled for turnover to operations in October, 1998.

Laser Airborne Bathymetry Survey (LABS) System

Faced with a growing backlog of hydrographic survey requirements in relatively shallow waters, in December of 1994, the former DMA and Navy signed a Memorandum of Agreement for the acquisition, implementation and operation of a Laser Airborne Bathymetry Survey (LABS) System. The LABS System will provide improved data collection capabilities, augmenting and enhancing conventional (ship/boat) capabilities, and will improve the quality and rate of collection of shallow water bathymetry. LABS will support IHO Standards based surveys against nautical charting requirements, provide a quick response capability for surveys in littoral areas of high importance, and contribute to the population of the Master Seafloor Digital Data Base (MSDDB) in the Hydrographic Source Assessment System (HYSAS).

An airborne laser bathymetry survey system is essentially a down-looking laser radar, typically operating in the blue-green region, with associated signal processing for determining water depth by measuring the arrival time difference between laser light pulses reflected from the surface and the bottom. Normally, the output of a pulsed laser is scanned perpendicular to the forward motion of the aircraft, creating a grid of soundings across a swath. Currently operational airborne laser sounder systems scan swath widths of 100 to 240 meters and provide laser spot spacing from approximately 3 to 30 meters along and across track. Operational airborne laser bathymetry survey systems have been fielded in Canada, Australia, Sweden and in the U.S. by the Army Corps of Engineers. The Canadian Larsen 500, fielded in 1984, was the first airborne laser sounder to provide data used in published charts.

Water clarity is a major limiting factor for the system's performance. The utility of LABS will be limited to relatively clear shallow waters. In waters of average clarity, depth determination to approximately 30 to 50 meters can be expected.

The acquisition and implementation of the LABS System is being managed by the DHI Joint Program Office within NIMA in Bethesda, MD. Upon delivery, the Commander, Naval Meteorology and Oceanography Command (COMNAVMETOCCOM) will be responsible for the operation and maintenance of the LABS System.

AERONAUTICAL CHARTING

Within NOS, the Office of Aeronautical Charting and Cartography (AC&C) meets the important requirements of civil and military aviation and the Federal Aviation Administration's (FAA) controller requirements. The aeronautical charting program consists of the compilation, printing, and distribution of charts and digital files of the United States and its territories to meet the requirements of civilian and military aviation. Approximately 15,000 aeronautical charts are produced annually for use by air flights in the National Airspace System. The continuous process of chart and digital data file maintenance is required to support the regularly scheduled update cycle for the program.

The aeronautical charting program is divided into three main activities: visual, instrument, and special products. Digital aeronautical data management is addressed under the Digital Cartography section.

Visual Program

The visual program produces 130 different charts that provide information to pilots flying under Federal Aviation Administration Visual Flight Rules (VFR). These charts are revised every 6 to 12 months, with approximately 2,500,000 copies distributed each year. The following additional tasks were performed by the visual program during fiscal year 1996.

- An Olympic Edition of an Atlanta Helicopter Route Chart for the 1996 Summer Olympics was published with an effective date of March 28, 1996. This first edition was designed for safe navigation in areas of high concentration of helicopter activity associated with the 1996 Summer Olympics. Five VFR Sectional Aeronautical Charts and four Terminal Areas Charts (TAC) which cover the many Olympic game sites were also published as special editions. All of these charts included the Temporary Flight Restricted Areas and other necessary aeronautical information associated with the Olympic venues.

- The 2nd edition of the Dulles Search & Rescue Chart was printed with an effective date of April 25, 1996. The new edition, printed on synthetic paper at a scale of approximately 1:125,000, provides coverage within 20 statute miles of the Dulles airport firehouse. A large scale inset at 1:24,000 on the reverse side provides coverage of all runways and the immediate surrounding airport property. In the production of this chart, all aeronautical and topographic line work was computer generated and photo-scribe positives were provided by the Reproduction Division.

- The existing Dallas-Ft Worth VFR TAC and Flyway chart were extended to accommodate the airspace changes effective with the implementation of the Dallas-Ft Worth Metroplex. The 1st edition of the Dallas-Ft Worth Helicopter Route Chart will be published to coincide with the implementation of the revised airspace. The Visual Chart Branch's production data base has been revised to reflect the extensive schedule changes required due to this project. Four VFR Sectional Aeronautical Charts, three Terminal Area Charts and three World Aeronautical charts are affected by the airspace changes.

- A new edition of the NOS Aeronautical Chart Catalog, dated 1996-1998, has been completed. The updated catalog lists several new products. The new catalog is scheduled for distribution to the public in October. Prices are listed on a one page insert.

- New editions of the NIMA Public Sale Nautical and Aeronautical Chart Catalogs were completed. The 3rd edition of the Nautical Catalogs includes nine regional catalogs. The 3rd edition of the Aeronautical Catalog will contain all new computer generated graphics. Graphics in both the Nautical and Aeronautical Catalogs will be maintained in a digital format. A new graphic will be included in the Aeronautical Catalog for a special edition of the Tactical Pilotage Chart for Bosnia and Herzegovina. The new catalog editions are scheduled for distribution to the public in October.

- A prototype chart of the Los Angeles Sectional was printed at the request of the Federal Aviation Administration. This prototype chart was presented at the Government/Industry Charting Forum for evaluation by the chart user community. This chart included several Charting Forum proposed recommendations concerning the portrayal of Terminal Area Chart and inset chart boundaries and the approach control frequencies data notes for Class C airspace. In the charting of these recommendations, a masking out procedure for the gradient and water tints was introduced to improve chart legibility.

- Color and black and white computer graphics of the Grand Canyon National Park were produced for the Federal Aviation Administration. These graphics reflect the proposed revisions to the Special Flight Rules Area boundary, the Minimum Flight Altitude Sector Boundaries and the Flight-Free Zones. The National Park Service used the Internet to provide the source information for the boundaries. The FAA and the National Park Service used these graphics in meetings and briefings to the aviation and legislative communities. These proposed changes will lead to a revised Grand Canyon VFR Aeronautical Chart in the near future.

- A 5 x 10 inch full panel extension of the Anchorage Terminal Area Chart is being produced for the December 5, 1996 chart edition. This extension is being produced in order to provide large scale chart coverage of the Whitter and Portage pass area located southeast of Anchorage.

- A 4th edition of the Chicago Helicopter Route Chart is in production for printing in November 7, 1996. A packet of updated information has been received from the Mid-West Helicopter Association. This new edition will be printed on synthetic paper.

- A new TAC for Cincinnati is being compiled. Chart paper size will be 30" x 30". A proposed effective date has not been established.

- The 10th edition of the U.S. Gulf Coast VFR Aeronautical Chart was published with a overlay of GPS helicopter routes. A new tabulation of route mileages and the associated geographic coordinates was introduced for this edition. These offshore routes are for authorized IFR helicopter use. The chart depicts offshore oil platforms updated from the Notice to Mariners and offshore mineral leasing areas and blocks established by the Bureau of Land Management.

Visual aeronautical charts are flight checked once every 3 years by a rotating crew of NOAA Commissioned Corps pilots flying a Government-owned twin engine "Shrike" Commander aircraft. During fiscal year 1996, the flight check program reviewed ten Sectional charts and their associated TACs. These flight checks contributed more than 900 potential base feature changes and in excess

of 1200 aeronautical changes for chart compilation. More than 167 photographic sites were compiled and 167 obstacles were measured. Of these obstacles, 14 were found to be new obstructions not previously contained in the obstacle data files; 14 obstacles were found to have been dismantled and were therefore relabeled in the current files; and 52 obstacles were reverified for horizontal position and vertical accuracy. This combined photograph and stereoplot operation yielded an outstanding 93 percent usable data return. The flight check program permits the resolution of source data inconsistencies and provides pilot input to the compilation and design of visual aeronautical chart products.

Instrument Program

The Instrument Approach Procedure Chart (IAP) program provides approximately 9,000 charts and products in 18 volumes, distributed throughout the world to civil and military pilots. This year, for the first time, the IAP volumes are being offered in both bound and loose leaf versions. Almost 20% of the charts are subject to revision every 56 days. To support this effort a Local Area Network and RBase database management software are utilized to cross reference charted items, including Airports, Intersections, Radio Facilities, and Special Use Airspace. The IAP Branch utilized its personal computers to develop finished copies for all Alternate, Take-off, and Radar Minimums, as well as the Indices for each volume.

The IAP Branch supports the Federal Aviation Administration (FAA) by quality controlling all procedural information on the FAA's Standard Instrument Approach Procedure and Standard Terminal Arrival (STAR) and Standard Instrument Departure (SID) before publication. Also the Branch produces 80 airport layout diagrams for the FAA's Aeronautical Information Publication (AIP). The Branch produces duplicate negatives for approximately 75% of the charts specified for inclusion in the National Imagery and Mapping Agency (NIMA) Flight Information Publication, Terminal Low Altitude IAP volumes.

The IAP Branch implemented the FAA's Global Position System (GPS) Overlay Program by adding information to over 3,600 existing IAP Charts. Additionally over 300 stand-alone GPS Charts have been published. The civil and military pilot may now use GPS as the sole source of navigation for non-precision approaches in the United States.
During fiscal year 1996, the following accomplishments were realized:

- The second edition of the IFR/VFR Low Altitude Planning Chart was produced in April 1996. This yearly chart replaces the Flight Case Planning Chart and the IFR/VFR Wall Planning Chart. The Planning Chart depicts low altitude airways, airports having an Instrument Approach Procedure or a minimum of 3000' hard surface runway, cities having a population of 5000 and over, state boundaries, important hydrographic features, Maximum Elevation Figures and a mileage table showing distances between 176 major airports.

- Off Route Obstruction Clearance Altitudes (OROCA) were added to the IFR Enroute Low Altitude Chart series. The OROCA is based on the highest known features, including terrain and obstruction, in a designated quadrangle, usually a one degree by one degree bin. A 1000' buffer is added in non-mountainous terrain and a 2000' buffer is added in mountainous terrain.

- 1995 Isogonic values were added to the IFR Enroute Low and High Altitude Enroute Chart series.

- Prototype Enroute Low Altitude Charts, Controller Charts and a new area chart depicting the new Dallas-Ft Worth Metroplex Airspace were provided to the FAA in August 1996. The charts will be use for training and final review of the massive airspace changes prior to the airspace implementation on October 10, 1996.

- The Controller Chart Automation Project was started this year. When completed, all 68 Controller Charts, including Alaska, the Bahamas, the Caribbean and parts of Central and South America, will be digitized. Digital files of "panels" may be combined to produce charts of any desirable geographical areas. Lithographic printing from negative plates will be replaced by automated files; drafting will be eliminated. Versatec paper copies from the digital files can be provided as requested. Phase 1 of the Controller Chart Automation Project, for the Western U.S., is near completion. Phases 2 and 3 will expand coverage to the Eastern U.S., Alaska, the Caribbean, and Central and South America.

- A new Fully Digital Arts Display (FDAD) system has been developed by the FAA for use in terminal air traffic control facilities. The system will replace the present analog video maps. Six major and two minor sites are scheduled for coverage by digital maps from the National Ocean Service, a total of 135 maps. At present, one site is operational; the remaining seven sites will be completed in six months. The video maps will be provided to the control towers on floppy disks and transferred to Erasable Programmable Read Only Memory (EPROM) chips at each site.

- Over 1443 Radar Video Maps (RVMs) were produced for 207 FAA Airport Surveillance Radars (ASRs) that serve 302 facilities. The video maps depicted on radar displays are entirely specified by the air traffic control facility. Each RVM presents an accurate and stable representation of the airways, fixes, boundaries, and runway extension lines that meet the unique requirements of each facility. All radar maps have been converted to digital files. This process has improved the accuracy of these maps and also made them available for use in other products.

Special Products and Services

AC&C continues its work in preparing for the upcoming large-scale changes to the National Airspace System around the Dallas-Ft Worth Metroplex. These major changes were effective on October 10, 1996 when NOS published the revised charts. AC&C has compiled and reviewed 100 of the 150 Instrument Approach Procedures, and all of the Low and High Airways, Standard Departures (SIDs), Standard Arrivals (STARs), Airspace Fixes, and Rule Dockets for the Class B airspace. Where data has been found to be in error, corrected data has been returned to FAA for publication by the FAA National Flight Data Center. The VFR and IFR Area Charts for Dallas-Ft Worth have been redesigned as a result of this project. Over 139 IAP Charts and 15 Standard Instrument Departure Charts have been added, resulting in 220 additional pages in the South Central 2 (Texas) IAP volume. This has forced the reconfiguration of the volume into two volumes, South Central 2 and South Central 3, dividing Texas at the 32nd parallel and increasing the number of volumes for the United States to 18. AC&C is utilizing its automated systems to quickly produce prototype charts and changes to existing charts. All data has been entered into digital files and made available to the chart compilers.

Airport Surveying and Mapping

The National Geodetic Survey (NGS) provides geodetic control for and map selected airports, and furnishes additional specialized products to the Federal Aviation Administration (FAA) and airline industry, thereby helping to sustain the nation's air transportation infrastructure. Through a combination of photogrammetric and ground survey techniques, NGS accurately determine the coordinates of obstructions to air traffic, aeronautical navigation aids, and runway end points, as well as other airport facilities.

Airport Obstruction Chart Surveys

An airport obstruction chart (OC) survey is an extensive geodetic/ photogrammetric operation providing aeronautical and related information to support a wide range of national airspace system activities. OC surveys extend the NSRS to the vicinity of an airport. This network consists of permanent survey markers that reference precisely determined latitudes, longitudes, and heights. It not only provides control for the current OC survey, but also supports future engineering projects, such as construction of runways and taxiways, establishment of aids to navigation, and obstruction clearing.

OC data are used to:

- develop instrument approach and departure procedures,
- determine maximum takeoff weights for civil aircraft,
- update official U.S. Government aeronautical publications,
- provide geodetic control for engineering projects,
- plan airport improvement/expansion programs,
- study land use in the airport vicinity,
- support miscellaneous activities, including environmental impact and other studies.

The hallmark product of the OC survey is the airport obstruction chart. This chart is a 1:12,000-scale graphic depicting Federal Aviation Regulations Part 77 surfaces, a representation of objects that penetrate these surfaces, aircraft movement and apron areas, navigational aids, prominent airport buildings, and a selection of roads and other planimetric detail in the airport vicinity.

Special Navigational Aid (SNA) Surveys

SNA surveys provide selected navigational aid and runway information for developing instrument approach procedures. These surveys, which may be conducted entirely off the airport premises, are usually limited in extent. All SNA survey positions and heights are related to the NSRS, or if NSRS values are not available, related to the local geodetic datum, which in turn can be related to the NSRS.

Area Navigation Approach (ANA) Surveys

ANA surveys provide runway and obstruction information for developing precision and nonprecision instrument approach procedures for navigation systems such as GPS and LORAN. In addition, these surveys provide positions and elevations for selected navigational aids associated with the airport. ANA surveys also establish a network of permanently marked geodetic control points in the airport vicinity. This network not only provides control for the current ANA survey but also supports future engineering projects.

Engine Out Departure (EOD) Surveys

EOD surveys provide runway and obstruction information for determining the maximum allowable takeoff weights for civil aircraft, assuming a complete failure of one engine. The obstruction information is furnished for the early climb segments out to 32,800 feet from the departure end of the runway. EOD surveys also establish a network of permanently marked geodetic control points in the airport vicinity.

GEOGRAPHIC NAMES

Access to Digital Geographic Names Information

In 1994 the digital holdings of foreign geographic names information maintained under the auspices of the US Board on Geographic Names (US BGN) was made available on the Internet. Since that time, Internet access has become the most frequently used method among NIMA/BGN customers to obtain geographic names spellings standardized by the US BGN.

Access to the data base is free of charge, and connection can be made through the NIMA Home Page on the World Wide Web at http://www.nima.mil/.

Additionally, a CD-ROM containing a copy of the Geographic Names Data Base has also been made available to those customers requiring world-wide names coverage. The title of the product is Digit Interim Geographic Names Data, and it may be obtained through the U.S. Geological Survey, the public sales agent for many of NIMA's products. The disk is termed interim as no software is included with the product; users must supply their own data base management software for viewing and manipulation of the file.

Quarterly reports are provided to the US BGN covering growth of the GNDB. the latest figures show that the GNDB contains over 4.6 million geographic name pertaining to over 3.3 million features around the world. It is the single largest systematically collected set of geographic names in existence.

The US BGN encourages cooperative projects with other countries to develop national policies for geographic names standardization and to implement technical means to carry out toponymic research using computer-assisted methods.

Publications

With the provision of digital geographic names data, the program of hard copy gazetteer production has been reduced. Nonetheless, gazetteers of the following areas were published in the 1994-1996 interval:

Bosnia and Herzegovina
Congo
Estonia
Lithuania
Malta
Rwanda

The *Foreign Names Information Bulletin*, containing decisions of the US BGN Foreign Names Committee, continues to be published on a quarterly basis. Ten issues have been released to date.

A new edition of *Romanization Systems and Roman-Script Spellings Conventions* was published in 1994. It contains tables explaining all of the romanization systems devised and jointly implemented by the US BGN and the Permanent Committee on Geographical Names for British Official Use (PCGN). Copies of all of these publications are available through the US Geological Survey.

Training

NIMA and the US BGN have supported geographic names training activities in an expanding number of areas.

The Pan American Institute of Geography and History continues to sponsor a yearly course in applied toponymy. The instructors are drawn from the US BGN staff at NIMA and USGS, and now includes an instructor from Honduras. The most recent two-week courses have been given in Lima, Peru, at the Instituto Geográfico Nacional in May-June 1995, and in Asunción, Paraguay, at the Servicio Geográfico Militar in May 1996. Plans are to hold the next course in La Paz, Bolivia, in the spring of 1997.

Additionally, US BGN staff from NIMA organized a seminar for the Eastern Europe Northern and Central Asia Division of the United Nations Group of Experts on Geographical Names that was held in Kiev, Ukraine, in May 1995. Experts from Armenia, Kyrgyzstan, Russia, Ukraine, and Uzbekistan participated. An additional seminar of this type is expected to be held in Riga, Latvia, in April 1997.

International Conferences

The US BGN has participated in a number of international geographic names conferences in the 1994-1996 period. The Seventeenth and Eighteenth Sessions of the United Nations Group of Experts on Geographical Names were held in New York in June 1994 and Geneva in August 1996, respectively. BGN staff from NIMA participated in United Nations regional geographic names sessions in Kiev in October 1994 and in Tallinn, Estonia, in October 1995. Staff members also took part in the Ukrainian Conference on the Standardization of Geographical Names in Kiev in November 1995.

The BGN held bilateral conferences with the British PCGN in November 1994 and October 1996, and recently attended the annual meeting of the Canadian Permanent Committee on Geographical Names in September 1996.

DIGITAL CARTOGRAPHY

Vector Map (VMAP)

This product line, formerly titled GEOMAP, was developed in response to the increasing use of Geographic Information Systems (GIS) in electronic battlefield and intelligence architectures. In addition to supporting requirements for detailed geographic analysis, VMap products are designed to meet background display dataset requirements. They facilitate the fusion of mapping, charting and geodetic (MC&G) data with a variety of databases and can serve as spatial data indices for situation graphics. The VMap family consists of:

a. VMap Level 0: a low-resolution digital product with feature density and attribution equivalent to the base map content of the hard copy Operational Navigation Chart and Jet Navigation Chart products. VMap Level 0 is currently scheduled for early 1997 completion. This product is a redesign of the current Digital Chart of the World (DCW) product. It will include the following enhancements: global vegetation (North American Library only in 1997), low-resolution bathymetric contours, offshore boundaries, International Hydrographic Organization (IHO) defined limits of oceans and seas, thematic structure consistent with other VMap databases, and use of the DIGEST Feature Attribute Coding Catalog. VMap Level 0 will incorporate up-to-date boundaries and country designators.

b. VMap Level 1: a medium-resolution digital product with feature density and attribution equivalent to that found on the hard copy 1:250,000 Joint Operation Graphic and equivalent medium resolution products. Initial production has begun and currently three Compact Disc's (CD's) have been completed: CD095, Korea; CD088, Turkmenistan (W); CD147, Eritrea.

c. VMap Level 2: a high-resolution digital product with feature density and attribution equivalent to that found on the hard copy 1:50,000 and 1:100,000 Topographic Line Map (TLM) products. An early hard copy conversion production capability was completed summer of 96 with a Bosnia/Skopje release. Full production capability from digital sources will follow.

d. VMap Level 3, Urban Vector Map (UVMap): a very-high-resolution digital product with feature density and attribution equivalent to that found on hard copy City Graphics, Military City Maps, or City Route Graphics. Initial production was begun in 1996 and three CD's have been completed to date.

Full Utility Navigation Demonstration (FUND) Software

To demonstrate the content and functionality of the Digital Nautical Chart (DNC), NIMA has developed demonstration software ,called "FUND", which by its nature also has nearly all the applications software capabilities required to exploit the DNC for marine navigation or GIS use. NIMA intends to make the FUND software available to foreign hydrographic authorities and to industry in general for their unrestricted use. It is available in either UNIX or Windows NT versions.

Geospatial Information Integrated Product Team

Since 1992 the former DMA has been planning and implementing its strategy for the creation of databases that support world wide coverage of accurate, current, spatially co-referenced information about the earth that is available

to users through an information architecture that allows for the management and dissemination of this information to a wide variety of users. In the summer of 1996 the former Defense Mapping Agency responded to The Defense Science Board (DSB) Task Force report, "Defense Mapping for Future Operations," September 1995, and established an integrated product team to address identified shortfalls in the implementation strategy. The report recognized the absence of a geospatial framework for a common operating environment, transparent user links, as well as, common analysis and exploitation tools. The Task Force made the following recommendations to address these shortfalls:

- Evolve a distributed heterogeneous Internet-like architecture that uses the geospatial databases as its foundation,
- Change the defense mapping mission to "Maintain the geospatial databases and protect access and integrity,"
- Institute a requirements process that prioritizes users geographic needs,
- Rapidly acquire access to virtual worldwide databases using all available commercial sources and practices,
- Equip and educate the end user to locally add value and meet his needs (e.g., smart workstations, printers, etc.), and
- Establish an Integrated Product Team (IPT) to manage the whole process.

The primary approach to the realization of the Geospatial Information Infrastructure, based on a the DSB recommendations, will be the IPT development of:

- A limited operational leave behind capability for those able to operate in the digital world of geospatial information (LOC October 1997), and
- A Geospatial Information Infrastructure Master Plan which describes the requirement for geospatial information, the "as-is" baseline available to support the requirement, the objective state to be achieved, the associated road map of activities and milestones for full scale development, and the required investment strategy to FY 2000.

United States Imagery and Geospatial Systems (USIGS) Architecture

The formation of National Imagery and Mapping Agency from the former DMA and numerous members of the imagery and intelligence community has resulted in a strategic thrust to modify and tailor the implementation of United States Imagery Systems (USIS) architecture by incorporating and integrating geospatial data extensions to the architecture. The result is the nascent development of the United States Imagery and Geospatial Systems (USIGS) architecture. The architecture will reconcile and integrate a common set of standards that supports the development of an enterprise wide infrastructure for developing and delivering Geospatial Information, Imagery and Imagery Intelligence to users. NIMA is currently in the process of developing the USIGS strategy and is actively consolidating current data models, procurement strategies and utilizing the Geospatial IPT to define portions of the overall strategic approach which integrates the USIGS architecture and the DPS migration program.

Digital Production System (DPS) Migration Program

In June 1994, the Intelligence Systems Board, acting under the direction of the Assistant Secretary of Defense for Command, Control, Communications and Intelligence (ASD[C3I]), identified DMA's Digital Production System (DPS) as one of 48 migration systems. In January of 1995 DMA published "Defense Mapping Migration Plan, Description for the Defense Mapping Agency's MC&G

Production System" and subsequently received funding to initiate a development program. The DPS had its Initial Operating Capability in 1991 but despite major technology breakthroughs in the development of an end to end digital cartographic production system the DPS was subject to a changing business environment that emphasized rapid response times, ability to accept new digital sources and the growing demand for geospatial information instead of products. The DPS migration will seek to retire current proprietary DPS capabilities at the end of FY 2000 which coincides with the end of the expected life cycle of the DPS system. The DPS migration program seeks to achieve the following goals and objectives that are consistent with the development of a geospatial infrastructure as defined by the GI IPT and NIMA business strategy for not only geospatial data but imagery and imagery intelligence through 2004 and beyond.

- To insure the use of NIMA data as the geospatial reference for planning, navigation and weapons systems guidance through interoperability and integration with customer systems. This goal supports the larger DoD vision for battle space dominance through information dominance

- To create a more efficient and productive NIMA infrastructure(eliminate redundancy, improved work flows, reduced maintenance costs) that supports the need for improved readiness and responsiveness for the war fighter while facing reduction in resources and end strengths

1:24,000-Scale Digital Line Graphs (DLG)

These vector files contain line data digitized from USGS topographic maps. Major data categories include: transportation, hydrography, boundaries, public land survey system, contours, vegetative cover, and non-vegetative surfaces. The NMD produces 1:24,000-scale DLG's using both appropriated funds and reimbursable funds provided by Federal and non-Federal cooperators. Through September of 1995, 70,026 1:24,000-scale DLG's were archived into the NDCDB. This total includes: 10,532 hydrography overlays; 10,433 transportation overlays; 19,781 boundaries overlays; 17,149 Public Land Survey System (PLSS) overlays; 3,749 hypsography overlays; 2,366 manmade features overlays; 2,010 vegetative surface cover overlays; 2,048 survey control overlays; and 1,958 non-vegetative features overlays.

1:100,000-Scale DLG

Five categories of 1:100,000-scale DLG data are currently available or in work for this map series: transportation, hydrography, PLSS, boundaries, and hypsography. Transportation and hydrography DLG's were completed nationwide under an agreement with the Bureau of the Census to assist in the 1990 Census of Population. The NDCDB archive status of the remaining three layers, through September of 1996, is as follows: 1,090 PLSS files (76 percent complete); 1,281 hypsography files (69 percent complete); and, 1,380 boundaries files (75 percent complete). The NMD expects to complete nationwide coverage for the boundaries layer in calendar year 1996.

1:2,000,000-Scale DLG

The revision of the boundaries, hydrography, and transportation DLG's from the 1:2,000,000-scale data base were completed for 49 states and the District of Columbia during calendar year 1994. Public Land Survey and Manmade feature (e.g. populated places) information were added and Federal land ownership was expanded in the boundary category. Additionally, these files have been converted to the Spatial Data Transfer Standard (SDTS) format, and are

available for public distribution on a variety of media types. Work is currently underway to complete Alaska, Puerto Rico, and the U.S. Virgin Islands. In addition, text files containing Federal land names are being collected and related to the corresponding feature in the DLG. With completion of this second phase of work in late 1996, the 1:2,000,000-scale data base will provide a single source for the most comprehensive Federal lands inventory available to date.

Digital Elevation Models (DEM)

A DEM consists of a regular array of elevations referenced horizontally either to a Cartesian Universal Transverse Mercator (UTM) or a geographic coordinate system. Spacing of the grid cells are arranged in a row by column format from south to north in profiles ordered from west to east. Vertical Elevations are in decimal or whole units of meters or feet with exception to the 1-degree DEM, which is distributed in whole meters.

The USGS produces the following five types of DEM data:

- 7.5-minute DEM (30- by 30-meter grid spacing typical, other normal variant spacings are 5- by 5-meter, 10- by 10-meter, and 15- by 15-meter, cast on a UTM projection) are produced in 7.5- by 7.5-minute blocks. Each product provides the same coverage as a standard USGS 7.5-minute quadrangle without overedge. Coverage 65% complete: Contiguous United States, Hawaii, and Puerto Rico.

- 2-arc-second DEM, formerly the 30-minute DEM (2- by 2-arc second data spacing). Consists of four 15- by 15-minute DEM blocks. Two 30-minute DEM's provide the same coverage as a standard USGS 30- by 60-minute quadrangle. Saleable units are 30- by 30-minute blocks, that is, four 15- by 15-minute DEM's representing one half of a 1:100,000-scale map. Coverage 50% complete: Contiguous United States, and Hawaii.

- 1-degree DEM (3- by 3-arc second data spacing). Provides coverage in 1- by 1-degree blocks. Two products (three in some regions of Alaska) provide the same coverage as a standard USGS 1- by 2-degree quadrangle. The basic elevation model is produced by or for the National Imagery and Mapping Agency (NIMA), but is distributed by the USGS in the DEM data record format. Coverage complete: United States.

- 7.5-minute Alaska DEM (1- by 2-arc second data spacing, latitude by longitude). Provides coverage similar to a 7.5-minute DEM, except that the longitudinal cell limits vary from 10 minutes at the southernmost latitude of Alaska to 18 minutes at the northernmost latitude limits of Alaska.

- 15-minute Alaska DEM (2- by 3-arc second data spacing, latitude by longitude). Coverage is 15 minutes of latitude by 20 minutes of longitude at the southernmost latitude of Alaska, to 36 minutes of longitude at the northernmost latitude limits of Alaska. Coverage of one DEM corresponds to a 1:63,360-scale quadrangle.

Digital Raster Graphics (DRG)

The USGS has completed development of product specifications for DRG's, an inexpensive product which consists of a raster image of the standard USGS topographic map series. To produce a DRG, published paper maps are scanned using high resolution scanners, and the data are then georeferenced and fit to

the UTM grid. Final DRG products can be easily combined with other digital cartographic data to create derivative products. For example, combining DEM and DRG data will produce a shaded relief contour map, and adding DOQ data to DRG's produces an orthophotomap. Derivative products can be static data sets, or they can be produced dynamically by GIS application software. Ongoing DRG activities include developing software and procedures for production, a majority of which will be done through an Innovative Partnership with Land Information Technology, LTD. The NMD estimates that 28,000 DRG's will be produced in fiscal year 1996.

National Digital Cartographic Data Base (NDCDB)

Development projects to enhance and improve data management operations for the NDCDB are continuing. A Sales Data Base (SDB) is being developed to provide digital products to customers on a variety of distribution media in an automated fashion. One enhancement to the SDB is that selected digital products have recently been made available over the Internet. These include the 1:100,000-scale DLG hydrography and transportation layers in SDTS format; 1:2,000,000-scale DLG's (will be available in SDTS format later this year); 1:24,000-scale DLGs, 1:100,000-scale hydrography and transportation DLG's (in DLG-3 format); 7.5-minute, 2 arc-second DEMs and 1-Degree DEM's. Other enhancements to the NDCDB include the implementation of new procedures for the archive and distribution of digital orthophotoquad (DOQ) data. In addition to the over 15,000 DOQ's currently available to the public, there are also 51 county-based CD-ROM's of DOQ data available. Further, the 1:100,000-scale hydrography and transportation digital line graph CD-ROM series was completed and is available for distribution. For more information on products and data availability, contact the USGS Earth Science Information Center general information line at 1-800-USA-MAPS, or access the USGS home page site via Internet at URL http://www.usgs.gov.

Geographic Information Systems (GIS)

The rapid development of GIS technology continues. Mathematical modeling, visualization, statistical analysis, object oriented systems, artificial intelligence, and neural networks are being merged with GIS's; multiscale, multisource, temporal, vector, and raster data are being integrated with GIS's. The scale of applications is expanding from regional to global. Some applications, such as forest fire control and airborne pollution can be operated in real time. Desktop publishing is available to move GIS analytical output and displays directly into publications. GIS technology is used in decision support systems and policy analysis and has become an integral part of map production and revision.

The USGS is developing cost effective techniques for using remotely sensed data (satellite and aircraft) and for merging and analyzing these data with digital cartographic, geologic, hydrologic, and other earth science data sets to build comprehensive GIS's to inventory, monitor, and manage natural resources. Recent research accomplishments include: (1) algorithms and data processing procedures for automated derivation of hydrologically related terrain characteristics from DEM's; (2) procedures to enhance and merge satellite image data with other earth science data sets; (3) techniques for using topographic, cartographic, and geochemical data sets for modeling the occurrence of toxic elements such as radon and selenium; (4) prototype software to exchange data between a number of different GIS's; and (5) assistance to other GIS users in linking disparate spatial data bases and in conducting GIS projects that apply to local, State, national, and international earth science projects.

The USGS participates in cooperative remote sensing and GIS demonstration projects and training activities. The purpose of cooperative projects and training courses is to transfer remote sensing and spatial data analysis techniques to environmental scientists of other organizations.

The NIMA's Global Geospatial Information System(GGIS) initiative represents a response to recent changes in the global political and technological climate. GGIS is one approach to the new challenge for the mapping and charting community to better manage geospatial data globally. GGIS is compatible with the most sophisticated GIS technologies. It employs user-accessible databases in a data warehousing or federated architecture. GGIS will contain a wide variety of information and data sets will be compliant with international, government, and industry standards. Layers of the database will include ortho-rectified and geocoded imagery, precise geodetic position centerline features (with the necessary attributes), terrain and sea floor elevations, and gravity and safety to navigation data Information describing the data will accompany the data sets to support the exploitation software packages used by the customer. GGIS will use fiber optics, asynchronous transmission, and communication satellites to establish high speed reliable highways of information between the producer and customer. Customers will have compact computers which have the capability of receiving heavily attributed data sets and allow tailored applications in offices, on ships, in space, or wherever high quality geospatial information is required.

Digital Line Graph-Feature (DLG-F)

The USGS faces the task of providing users with up-to-date digital data and, at the same time, enhancing the structure of that data to meet changing needs. It is not sufficient to automate the mapmaking process for reproducing graphics; spatial data users require a data structure that can support complex queries and the analysis of thematic information to answer national (and global) problems.

To address this need, the USGS has created a modernized and enhanced version of its DLG vector data structure called DLG-F. This new structure is feature-based to resemble the way physical surroundings are perceived. The features shown on a map, such as roads, streams, or buildings, are represented by corresponding "features" encoded in the digital file. Over 200 features derived from USGS topographic maps have been defined. These features are further described by attributes that define such characteristics as name or function and by relationships that describe such interactions between features as flow through a network or features that bound one another.

Ultimately, all features in the DLG-F model are linked to the spatial components that comprise them: polygons, chains and nodes. The expression of topology occurs at the spatial level in the file, just as in existing DLG files. The current DLG files, however, also encode feature-level information at the spatial level through a series of attribute codes attached to each spatial element. This limitation serves to point out the most important advantage of DLG-F - the separation of spatial components from nonspatial components for more flexibility in manipulating the data base.

Implementation specifications are being generated to explain how spatial data is described and manipulated. These specifications are currently being developed for the 1:24,000- and 1:100,000-scale map series and include delineation specifications describing what a feature looks like on the ground; extraction specifications describing when a feature is collected from the source for inclusion in the data base; representation rules describing how a

feature is represented in the data base; product specifications describing when a feature from the data base is included on the graphic; and product generation rules providing for symbolization, generalization, conflict detection and resolution, and names and label placement for graphic production. A standards data base is being developed that will integrate DLG-F rules and content specifications directly into data collection and production operations.

A DLG-F production system is under development that will collect, revise, and validate digital spatial data. A prototype system has been built and test data sets have been generated. The DLG-F data model provides the USGS with a flexible tool to support the Nation's fast-growing spatial data needs into the next century.

The Spatial Data Transfer Standard (FIPS 173)

A major milestone for the spatial data community occurred on July 29, 1992 - the approval of the Spatial Data Transfer Standard (SDTS) as Federal Information Processing Standard (FIPS) Publication 173. The SDTS facilitates the transfer of digital spatial data between dissimilar computer systems. FIPS 173 became effective February 15, 1993; use of the standard was mandatory for all Federal agencies 1 year from this date.

The USGS, as the FIPS 173 maintenance authority, is committed to involving the spatial data community in various activities to promote acceptance of FIPS 173 and support FIPS 173 implementations. Additional approvals are being sought from the American National Standards Institute and the International Standards Organization (ISO) to broaden access to the FIPS 173 among the commercial and international communities.

The USGS will coordinate the development of profiles within the user community to ensure maximum consistency among all FIPS 173 profiles. A profile is a clearly defined and limited subset of a standard that is designed for use with a specific type of data. The first of these profiles, the Topological Vector Profile (TVP), has been approved by the National Institute for Standards and Technology (NIST) as an amendment (Part 4) to FIPS 173. USGS SDTS-formatted DLG data is now available from the USGS Sales Database at Sioux Falls, South Dakota. Current data available includes national coverage of 1:100,000 and 1:2,000,000 DLG's; the 1:24,000 DLG's will be available beginning in the fall of 1996.

The USGS has completed development of a Raster Profile, but further refinement is anticipated in an ongoing effort to harmonize the SDTS Raster Profile with an existing image transfer standard now used by the National Imagery and Mapping Agency (NIMA). The Raster Profile, which will be Part 5 of the SDTS once approved by NIST, will be used to transfer USGS Digital Elevation Models (DEM) and Digital Orthophoto Quadrangles (DOQ). The raster profile will probably be limited to georeferenced data, sampled uniformly and in a geodetic or cartographic coordinate system, rather than including raw sensor data.

The USGS has recently collaborated with the National Oceanic and Atmospheric Administration (NOAA) on the development of a Point Profile for the transfer of geodetic control data. This profile will be submitted to NIST for approval as FIPS 173 Part 6.

Additional profiles, such as those for State and local, utilities, and graphics profiles, will also be considered in the future.

In addition, the USGS is developing a suite of public domain software tools designed to support the encoding and decoding of logically compliant FIPS 173 data in and out of the required ISO 8211/FIPS 123 physical file implementation. The USGS is designing a spatial data transfer processor to support FIPS 173 transfers of its own digital spatial data. Requirements for conformance testing software have been determined by the spatial data community. Development of conformance testing software and testing methodology is complete and now undergoing evaluation at selected beta sites; NIST will coordinate the formal validation process following beta test results and release of the conformance software.

Part 2 of FIPS 173 presents a standard model for a spatial features data dictionary and a list of terms and definitions for entities and attributes. This model currently contains only a limited set of hydrographic and topographic features. For part 2 of FIPS 173 to be useful, additional terms and definitions must be included for other types of data. The USGS has been authorized by the NIST to establish a FIPS Spatial Features Register to accomplish this effort. A strategic plan to maintain part 2 using the FIPS Spatial Features Register is being developed and will be completed at a national forum to be held early in 1993. The FGDC is actively involved in developing the register and cosponsoring this forum. Because the register will allow users to update the glossary continuously, part 2 of FIPS 173 will evolve over time.

Implementation of the National Spatial Data Transfer Standard

The SDTS was approved by the Department of Commerce as the Federal Information Processing Standard in July 1992. The SDTS serves as the spatial data transfer mechanism for all U.S. Federal agencies and is available for use by State and local governments, private sector, and research organizations. The standard is valuable to users and producers of digital spatial data for reduced information loss in data exchange, for the elimination of the duplication of data acquisition, and for increased quality and integrity of spatial data. The USGS has been designated the SDTS maintenance authority and is engaged in developing software tools, conducting training and workshops, and developing a spatial features register. The USGS is continuing the effort of conversion of legacy DLG data to the SDTS format; DEM legacy data conversion will begin in mid-September of 1996. Routine production of SDTS data sets will closely follow completion of the legacy data conversion effort.

Geographic Data Clearinghouse

The U.S. Federal Government, as a first step toward an NSDI, has established a National Geographic Data Clearinghouse under the auspices of the FGCD. The clearinghouse provides nationwide access through the Internet to directories of information about geographic data sets held by Federal agencies, State and local governments, academia, and the private sector. In some cases these data sets are available on-line.

Framework Concept and Implementation

The USGS is taking an active role in supporting the development and implementation of the NSDI framework concept. The purpose of the framework concept is to organize the collection and maintenance of the basic, consistent digital geospatial data which can be shared and provide a base on which an organization can accurately register and compile other themes of data. Shared

collection and maintenance will leverage resources across organizations for data collection and maintenance, reduce duplication of effort, allow organizations to focus on their primary business, and ultimately increase data availability over broader geographic areas in a more timely manner.

The framework development and implementation are being managed by a consortium of representatives from Federal, State, and local organizations, under the auspices of the Federal Geographic Data Committee (FGDC). The USGS is coordinately closely with FGDC to ensure its digital mapping programs are consistent with FGDC-endorsed framework guidelines.

The USGS has comprehensive knowledge about geospatial data and related technologies and a core capability for the production and integration of geospatial data adhering to framework guidelines. USGS will actively serve as a catalyst to (1) help define, develop, and promote geospatial data standards and coordinate their use, and (2) establish cooperative partnerships with other Federal, State, local, and private sector organizations to establish common approaches to data sharing and maintenance, data acquisition, and data integration as well as enabling the technologies to support the implementation and maintenance of Framework.

The USGS is currently participating in cooperative agreements with the U.S. Environmental Protection Agency, Bureau of the Census, and Bureau of Land Management to establish common geospatial data for transportation, hydrography, boundaries and cadastral themes. Through these agreements the USGS and their joint partners are pursuing other data partnerships at the State, local, and private levels to collaboratively develop geospatial data adhering to Framework guidelines. These data will support major programs such as Census 2000, Clean Water Act, Natural Resource and Range Management, and Ecosystem initiatives.

Additionally, USGS serves as the theme manager for developing and implementing the national digital orthophoto imagery and digital elevation components of the Framework. These national programs are working models on how Federal, State, and local governments, as well as private industry, can participate and leverage resources to develop common geospatial data and ultimately building the Framework.

Computer-assisted Compilation

During FY 96, the Marine Chart Division (MCD) of the Coast Survey continued to enhance its automated chart production system. The production system progressed from automated drafting into the development and implementation of Computer Aided Compilation (CAC). Cartographers are evaluating source document information and applying data directly to digital versions of the charts, eliminating manual compilation process steps. Digital data is imported into CAC and compilation decisions, such as evaluation and data selection, are made on the computer screen. The data are then rasterized, creating digital raster images of each chart. The CAC process has enabled the Marine Chart Division to decrease throughput times in the application of data since it is no longer necessary to manually apply data and then scan it into the production system.

The Marine Chart Division maintains vector and raster databases that are part of the CAC process. A raster file exists for every color separate of every chart for a total of approximately 10,000 files. Approximately 2500 vector design files are maintained, one for each chart, inset, and extension. Revisions to the chart are incorporated into a vector design file and then

rasterized into the existing raster color separates. When a new edition of a chart is required, the revised raster files are used to generate a new set of pre-press negatives for print. As a no cost by-product, new editions of digital raster chart images are produced. The same files are disseminated to the Cooperative Research and Development Agreement (CRADA) partners to produce a Raster Nautical Chart (RNC), a raster copy of the new paper chart edition.

Raster Nautical Chart Project

In 1994, NOS signed a Cooperative Research and Development Agreement (CRADA) with BSB Electronic Charts to perform research and development on electronic charts, chart data, systems, and software, and to commercialize the results of this research and development effort. The first product from this partnership is the commercial version of the NOS Raster Nautical Chart. Retail availability of the Raster Nautical Charts began in May 1995 and by January, 1996, the entire suite of 1,000 NOS Charts was available on CD-ROM and floppy diskettes through NOS Chart Agents.

Thematic Vector Electronic Charts

The Marine Chart Division has been contributing to development of an electronic chart display and information system (ECDIS) for a number of years. In order to respond to the current needs of the mariner, particularly commercial and defense users, the Division has undertaken development of a thematic vector electronic chart product. The majority of the information on the thematic vector hybrid chart is in raster form. However, the most navigationally significant data (e.g., channel limits, traffic separation schemes, aids to navigation, etc.) are in vector form and standards-compliant except for reduced content. The thematic vector design will support the real-time navigation and collision/grounding avoidance needs of the commercial mariner, and accommodate the real-time tide and current updating capability so essential for pilots.

The proposed vector data set of the thematic vector product would have the following characteristics: very large scale (1:2500), IHO S-57 format, current to within one week at all times, only available as an electronic product and only available electronically, expandable with private data , and up-datable with real-time tides and currents. The data would not be suitable for general navigation by groups such as recreational boaters or for large-scale naval operations. While many items on a chart such as shoreline, depths, landmarks, and inshore information would not be included, the new Raster Nautical Charts described above may be used concurrently with the vector data to form a reduced-ECDIS and provide general navigation information in the surrounding areas.

A prototype data set was completed in February 1996 as part of the NOS San Francisco Bay Demonstration Project. New options are being explored to streamline in-house data collection and the importation and processing of data from other government and private sources.

Digital Aeronautical Data Management

AC&C has started building an Aeronautical Terrain Database (ATDB) to support the MSAW (Minimum Safe Altitude Warning) system. The ATDB will include coverage of all of the U.S. An extensive statistical survey has already been done of available data sources, including manually compiled MSAW files. The ATDB will be built from a number of data sources and normalize them to a

single format, accuracy and resolution. The earth center geographic reference system will be used.

The Aeronautical Chart Automation Branch has completed building a Visual Sectional Chart database of the contiguous U.S. The data is in raster format and is delivered at 125 dpi and 240 colors. A single, normalized color palette is used to map the entire contiguous U.S. The data is currently updated every 28 days and delivered to the FAA for the Instrument Approach Procedure Automation project.

REMOTE SENSING/IMAGERY PROCESSING

National Aerial Photography Program (NAPP)

NAPP contracts awarded in fiscal year 1996 cover all or part of the States of Kansas, Maine, Minnesota, Mississippi, Montana, New Mexico, Texas, West Virginia, and Washington. The fiscal year 96 contract awards concluded the second five year cycle of the NAPP, which will change to a seven year acquisition cycle starting in fiscal year 1997. The States currently under consideration for fiscal year 1997 are Alabama, Arizona, Kentucky, Michigan, New Hampshire, northern New Mexico, Tennessee, and Utah.

Digital Orthophoto Quadrangles (DOQ)

The National Digital Orthophoto Program is administered by representatives of the USGS, the Natural Resources Conservation Service, the Farm Service Agency, the Forest Service, and the National States Geographic Information Council. This group coordinates technical standards for the 3.75-minute (quarter quadrangle) DOQ product, develops funding strategies, monitors production costs, and develops annual plans for the program.

To meet the enormous production requirements of these and other Federal and State agencies, and in addition to its own smaller in-house production capability, the USGS manages a multi-year professional services contract with seven pre-qualified vendors. The NMD provides source materials and quality control services for this contracted production work. As shown below, since fiscal year 1993, funding for contracted production of DOQ's has steadily increased.

Fiscal Year	Contracted $	DOQ's Produced
1993	1.6 million	2,750
1994	3.7 million	7,350
1995	4.8 million	11,950
1996	13.9 million	19,100

To date, the USGS has completed and archived into the National Digital Cartographic Database 32,680 quarter quad DOQ's with an additional 43,230 authorized for production. Completion of 24,000 DOQ's are planned for fiscal year 1997, at an estimated contract cost of $25 million. A graphic displaying DOQ data holdings can be found at the following USGS web site:

http://www-nmd.usgs.gov/metadata/doq.html.

Satellite Image Mapping

The USGS printed the 1:5,000,000-scale map of Antarctica using advanced very high resolution radiometer (AVHRR) data from NOAA satellites. The project was done as a cooperative effort among NOAA, the USGS, and the United Kingdom Royal Aircraft Establishment National Remote Sensing Council. The primary image combined bands 1 and 2 (visible and near-infrared) in a 1:5,000,000-scale image of the Antarctic Continent. An insert showed the data from the thermal band. A second edition is planned using the images as a base for topographic contours and geographic names. In addition, the USGS has printed six image maps at 1:250,000 scale around Ross Island using Landsat multispectral scanner (MSS) data. Work is also in progress on ten image maps at 1:250,000 scale using Landsat thematic mapper (TM) data covering Ice Streams on the Siple Coast. Mosaicking is complete for the first five maps

and digital processing is continuing on the next five maps. Image maps of 17 MSS scenes are being prepared to support USGS mapping requirements for nine 1:250,000-scale quadrangles on the Antarctic Peninsula.

The USGS, in cooperation with the Canada Centre for Remote Sensing, processed AVHRR data acquired from August 11 to 20, 1990, to produce a vegetation index map of North America. The vegetation information extends from northern Canada to the southern tip of Panama. The colors on the map represent the vegetation vigor and density for those 10 days. The map was printed in time to be distributed at the Global Forum of the United Nations Conference on Environment and Development in Rio de Janeiro, Brazil, in June 1992. A second map under preparation shows the vegetation vigor for the conterminous United States. Both of these maps were prepared from digital data on tape that was plotted on halftone film. Any necessary editing was done on an edit station attached to the plotting system.

A 73-scene MSS image mosaic of Pakistan was completed. Other products include a full country mosaic (150-meter pixels) reproduced at 1:2,000,000 scale, two maps (100-meter pixels) reproduced at 1:1,000,000 scale, and seven maps (50-meter pixels) reproduced at 1:500,000 scale.

OTHER PROJECTS

Mekong River Basin

The Mekong River Basin drains parts of southern China, eastern Burma, most of Laos, eastern Thailand, most of Cambodia, and southern Vietnam. These nations vary widely in levels of development and interests in the river. However, all are attempting to increase the rate of development in their nations to improve the living standards of their people. There are strong internal and external development pressures on the river basin that may result in significantly altered functional characteristics of the river. The region suffers from a severe lack of data and information with which to make development decisions that have potential long-term positive and negative effects. Although numerous studies have been conducted to improve understanding of the aquatic species that support the existing economy in much of the basin, the studies are often incompatible and many lack the spatial and temporal components necessary to make them useful for ecological planning in development projects.

Monitoring the change in water quality (both surface and ground) are necessary. Terrestrial information is limited as well. Detailed land cover and soils data are necessary for long-term agricultural and renewable resource exploitation planning. Nominal 1 km resolution greenness data are available based on the normalized difference vegetation index derived from advanced very-high resolution radiometer weather satellite data. Landsat Thematic Mapper and SPOT data can be used to develop higher resolution land cover data. Historic satellite data that are useful for change detection exist as part of the Landsat data archive at the USGS' Earth Resources Observation System (EROS) Data Center (EDC). Topographic data at a 30-arc second resolution derived from NIMA's 1:1,000,000-scale Digital Chart of the World by the USGS are available for the region. This is a resolution suitable for basin-wide analysis, but not project planning. Other topographic data are available as well, as part of the DCW.

Pakistan Remote Sensing Image Mapping

As part of a program sponsored by the U.S. Agency for International Development between 1985 and 1993, a series of satellite images of Pakistan were obtained by the USGS and geometrically corrected to provide cartographically correct base maps. These images were used internally for geologic mapping and energy exploration programs conducted cooperatively by the USGS and the Geological Survey of Pakistan. The USGS is using the data obtained from this program to develop a set of prototype maps to demonstrate the utility of producing geometrically corrected imagery available to the public at reasonable costs. MSS imagery of Pakistan in the Lambert Conformal Conic projection will be released in seven sheets at a scale of 1:500,000 and one sheet at a scale of 1:2,000,000 (USGS Miscellaneous Investigations Maps I-2587-A through H, January 1997). Subject to funding, selected scenes of color composited Landsat Thematic Mapper images in the visible (TM1), near infrared (TM2), and mid-infrared bands (TM7) will be released in the UTM projection at a scale of 1:250,000. A scalable CD-ROM of the MSS data is also being planned. The published image maps useful to earth scientists in general, could also help companies engaged in energy and mineral exploration, infrastructure development, and baseline environmental monitoring in Pakistan.